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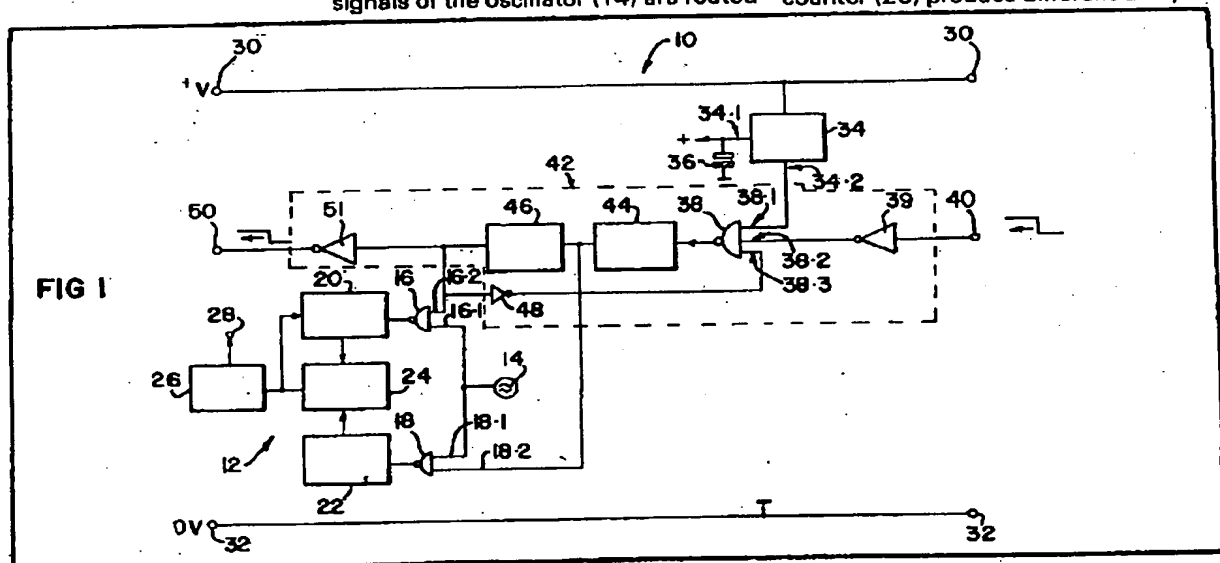
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## (54) Sequential Detonation of Explosions

(57) Activating modules 10 are connected in parallel at 30, 32 across the output of a shot exploder (52, Fig. 2, not shown) which supplies a series of calibrating signals. The first calibrating signal calibrates the first module in the series and successive calibrating signals calibrate successive modules. After each module has been calibrated it supplies a mode switching signal to module, so that the said next module responds to the next calibrating signal and is calibrated by it. Each module has an internal oscillator (14), a calibrating counter (22), a timing counter (20) and a comparator (24). The timing signals of the oscillator (14) are routed

to the counters (20, 22) via gates (16, 18). A mode control section (42) supplies a calibration mode signal to the gate (18) and a timing mode signal to the gate (16) so that the signal from oscillator (14) are counted in counter (22), (20) during a calibration mode and a timing mode respectively. The mode control section (42) supplies the calibration mode signal when it receives a mode switching signal at an input terminal (40) and a calibrating signal from the shot exploder via a pulse discriminator (34). The timing mode signal is supplied at the end of the calibrating signal, a mode switching signal being then also supplied to the next module via an output terminal (50). In the timing mode, the count of the timing counter (20) is compared by a comparator (24) with the count accumulated in the calibrating counter (22) during the calibrating mode. When the counts are equal the comparator (24) adds one to the count of a delay counter (26) and resets counter (20) to start counting from zero again. When the delay counter (26) has a count of 32 an activating signal is supplied to the detonator connected to that module via terminal (28). The successive calibrating signals may have different deviations so that the corresponding counter (26) produce different delays.



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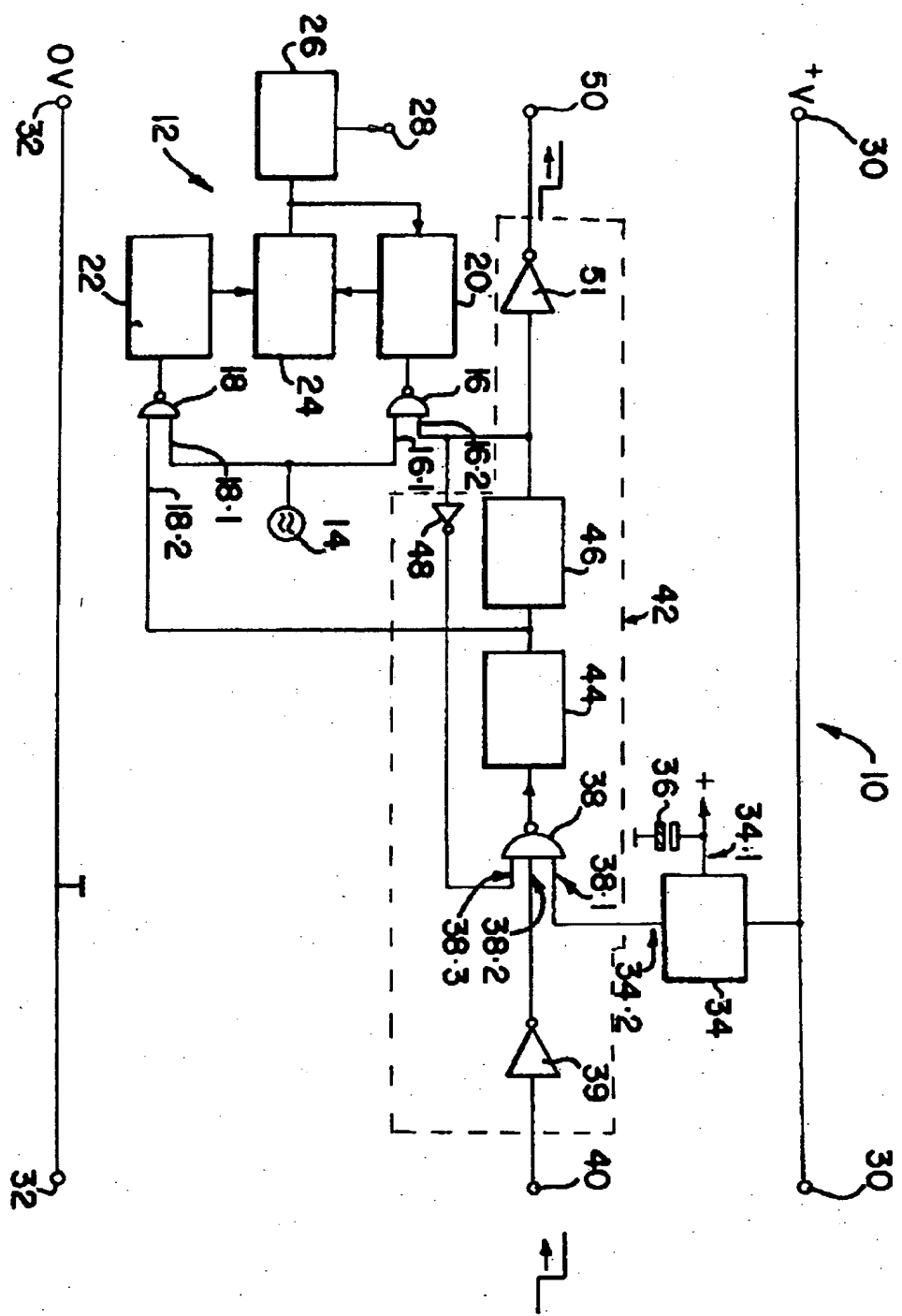
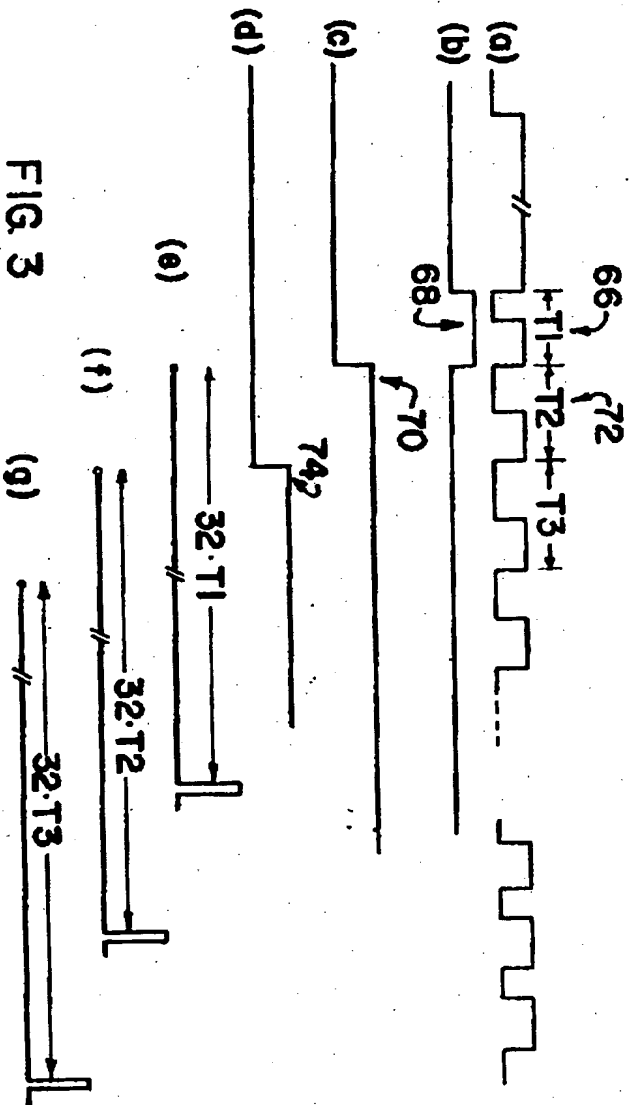
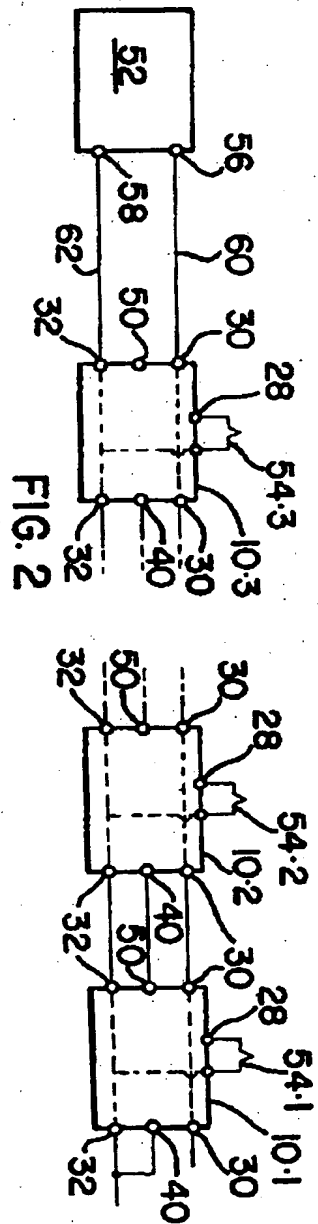


FIG 1



## SPECIFICATION

## The Sequential Detonation of Explosions

The applicant is aware of a suggestion for a detonating system which has a series of activating modules which are all remotely supplied, simultaneously, with a calibrating time signal which determines the intershot time interval. Each module has a local oscillator, two counters and a comparator. Thus, a first one of the counters counts the number of signals supplied by the oscillator during the calibration period and the second counter then counts the number of signals supplied by the oscillator in operation and when the comparator detects that the two counters have the same count it supplies a signal which resets the second counter and also increases the count of a third counter. When the third counter has counted a predetermined number it supplies an activating signal to a detonator.

With the abovedescribed suggested system calibration of all the modules takes place before a first module in the series is activated. The accuracy of the modules is determined by the stability of the oscillators of the modules. Thus the oscillator of the last module must be sufficiently stable for a time period of  $T+nt$  where  $T$  is the interval between finalisation of calibration and activation of the first module,  $n$  is the number of modules, and  $t$  is the intershot interval. Further, with the abovedescribed suggested system, the intershot interval is fixed for all the modules.

In an attempt to overcome or minimise these disadvantages it is proposed that the modules be successively calibrated.

Thus, according to the invention there is provided an activating module for a sequential activating system having a series of the modules, which includes

- 40 a timing signal generating means for generating a timing signal;
- a mode control means for supplying a calibration mode signal, an operative mode signal, and an output mode switching signal to be supplied to a successive module in a series thereof;
- 45 a calibrating recording means for recording the timing signal when in a calibration mode and for supplying a recorded calibration signal;
- an operative timing signal determining means responsive to the mode control means for determining when the timing signal generating means has generated an operative timing signal, when in the operative mode, that has a predetermined relationship to the recorded calibration signal and for supplying a prompting signal which is supplied directly to a detonator or to a further processing means when the operative timing signal has been generated;
- 55 a calibrating signal supply connection means for connecting the module to a shot exploder which supplies a series of calibrating signals for successive modules in a series thereof;
- 60 a first gate means, responsive to the mode control means, the output of which is supplied to

65 the calibrating recording means for enabling the calibrating recording means whilst the appropriate calibrating signal is extant;

a mode control input connection means for receiving an input mode switching signal that the module is to go into its calibration mode and for supplying the input mode switching signal to the mode control means;

70 a second gate means, responsive to the mode control means, connecting the timing signal generating means with the operative timing signal determining means; and

a mode control output connection means for supplying the mode switching signal to a successive module in a series thereof.

80 The timing signal generating means may conveniently include an oscillator. The oscillator may generate a series of signals. For example, the oscillator may generate a square wave or pulses. Thus, the calibrating recording means may include a calibrating counter for counting and recording the number of signals generated by the oscillator whilst the calibrating signal is extant. Similarly, the operative timing signal determining means may include a timing counter for counting the number of signals generated by the oscillator and a comparator for comparing the count of the timing counter with that of the calibrating counter and supplying an output signal when the two counts are equal. As a further feature, the output signal of the comparator may reset the timing counter which then starts counting again. The operative timing signal determining means may thus include a further counter for counting the number of times the comparator supplies its output signal and for supplying the prompting signal when it has counted a predetermined number. It will thus be appreciated that the time between shots will be the time duration of the successive calibrating signals and the number of modules that have been calibrated before the first detonator is activated will be dependent on the predetermined count of the further counter.

110 It will be understood that the mode control means supplies its calibrating mode signal when it has received its input mode switching signal and for the duration of the calibrating signal received thereafter. The mode control means may then supply the operative mode signal at the end of the calibrating signal received by it after receipt by it of the input mode switching signal, i.e. at the end of the calibrating mode. Further, the mode control means may supply the output mode switching signal at the same time as the operative mode signal. In order to ensure that the module does not react to any further input mode switching signals or calibrating signals, the mode control means may latch itself by means of the operative mode signal, to maintain supply of this signal.

125 In a preferred form, the control means supplies the calibration mode signal, after receipt by it of the input mode switching signal, for so long as it receives the calibrating signal, and the calibrating

counter then counts the number of timing signals generated by the oscillator during the duration of the calibration mode signal. In a preferred form, the control means may also comprise a network of logic and bistable elements.

It will further be appreciated that the module will need to be connected or connectable with a detonator. Thus, the module may include a detonator connection means for connection thereof to a detonator, an activating signal being supplied to the detonator either directly from the operative timing signal determining means or the further processing means.

Still further according to the invention there is provided a sequential activating system, which includes

a shot exploder for supplying power and a series of calibrating signals;

a series of modules according to the invention, with the calibrating signal supply connection means of each module being connected to the shot exploder, the mode control input connection means of a first module in the series being connected to the shot exploder, and the mode control input connection means of a second and each successive module in the series being connected to the mode control output connection means of its immediately preceding module.

The invention also extends to a method of activating a series of detonators which includes providing a series of activating modules;

supplying a calibrating signal to a first one of the modules and successive calibrating signals to successive modules in the series; and with each module

- a) generating internally a timing signal;
- b) placing it in a calibration mode;
- c) supplying it with the appropriate calibrating signal having a predetermined time duration;
- d) determining and recording the value of timing signal equal to that calibrating signal
- e) placing the module in an operative mode;
- f) determining when the timing signal generated during the operative mode has a predetermined relationship to the recorded value of the timing signal; and
- g) activating a detonator associated with that module when the timing signal generated during the operative mode attains the predetermined relationship.

The invention is now described, by way of an example, with reference to the accompanying drawings in which:

Figure 1 shows a circuit diagram of part of an activating module in accordance with the invention;

Figure 2 shows schematically how a series of activating modules are inter-connected with a shot exploder and detonators to provide a detonating system in accordance with the invention; and

Figure 3 shows a series of timing diagrams.

Referring to Figure 1, shown generally therein by reference numeral 10 is an activating module

has an internal timing arrangement 12 which comprises a local oscillator 14 which generates a square wave, two 2-input NAND-gates 16 and 18, a timing counter 20 and a calibrating counter 22, a comparator 24, and a divide-by-32 counter 26. The oscillator 14 supplies a signal of any frequency within predetermined design limits. The long term stability of the frequency of oscillation of the signal is not critical. The timing

arrangement 12 is calibrated by means of a signal supplied from a remote shot exploder (as will be discussed hereinafter with reference to Figure 2). As indicated, the square wave signal supplied by the oscillator 14 is supplied to inputs 16.1 and

18.1 of the gates 16 and 18. To place the timing arrangement 12 in a calibrating mode, a calibration mode signal is supplied to the input 18.2 of the gate 18. To place the timing arrangement 12 in an operative mode, an

operative mode signal is supplied to the input 16.2 of the gate 16. When the gate 18 is opened by means of a calibration mode signal supplied to its terminal 18.2, pulses are supplied to the calibrating counter 22. The calibrating counter 22

counts the number of pulses supplied by the generator 14 whilst in the calibration mode. This count is held by the calibrating counter 22. It will be appreciated, when in the operative mode, the timing gate 16 is opened and the square wave

pulses generated by the oscillator 14 are supplied to the timing counter 20, at substantially the same frequency as when in the calibration mode. The timing counter 20 counts these pulses, the comparator 24 comparing the count in the counters

20 and 22. When the timing counter 20 has counted the same number as that stored in the calibrating counter 22, the comparator 24

supplies a signal to the counter 26 and also a reset signal to the timing counter 20. The timing counter 20 then begins counting from zero again and when it has counted the same number as stored by the calibrating counter 22 a further

signal is supplied by the comparator 24. This carries on until such time as the counter 26 has reached a count of 32, at which time it supplies an activating signal to a terminal 28, to which in use an instantaneous electric detonator is

connected as is shown in Figure 2 and discussed hereinafter.

Power and calibrating signals are supplied to the module 10 via terminals 30 and grounded terminals 32. The module discriminates between DC power supply and calibrating signals by means of a pulse discriminator 34 which is connected to the terminals 30. The pulse discriminator supplies an inverted signal. If a DC energising signal is supplied this is routed by the pulse discriminator 34 to output 34.1 to which is connected an energy storage capacitor 36.

Calibrating signals are supplied, logically inverted, to an output 34.2. This output is connected to one of the inputs 38.1 of a 3-input NAND gate 38. A second input 38.2 is connected to a mode control input terminal 40 via an inverter 39 and a third

input 38.3 is connected to a feedback supply from

an inverter 48. The output of the gate 38 is supplied to a D-flip-flop 44 which in turn is connected to an R-S flip-flop 46. The D-flip-flop responds to a negative-going signal. As shown, the output of the flip-flop 44 is also connected to the input 18.2 of the NAND gate 18. Similarly, the output of the R-S flip-flop 46 is connected to the input 16.2 of the NAND gate 16. It is also fed back to the input 38.3 of the NAND gate 38 via the inverter 48. Finally, it will be noted that the output of the R-S flip-flop 46 is also connected to a mode control output terminal 50, via an inverter 51. The inverters 38, 48 and 51, gate 38, a flip-flops 44 and 46 constitute a mode control section.

In operation, when the module is energised, the flip-flops 44 and 46 are reset so that their outputs are low. This is accomplished by a suitable network (not shown) as is well known in the art. As a result of the inverter 48 a high signal is fed back to the NAND gate 38. When the module 10 is to be calibrated, a high signal is supplied to the input terminal 38.2 of the NAND gate 38 via a low signal supplied to the terminal 40 which is inverted by the inverter 39. When the next calibration signal arrives at the module 10 via the terminal 30 it is inverted and routed by means of the pulse discriminator 34 to the input 38.1 of the NAND gate 38. The output of the NAND gate 38 accordingly goes low, changing the state of the flip-flop 44. A high signal is then supplied by the flip-flop 44 to the NAND gate 18 and pulses are accordingly routed to the counter 22 as described above. At the termination of the calibrating signal the output of the NAND gate 38 again goes low, changing the state of the D flip-flop 44 which in turn sets the flip-flop 46 whose output accordingly goes high. This signal which is supplied to the NAND gate 16 places the timing arrangement 12 in its operative mode and timing commences. The signal that is fed back to the NAND gate 38 is low which accordingly disables the NAND gate 38. The output of the flip-flop 46 thereafter stays high. A low signal is also supplied at the terminal 50.

Reference is now made to Figure 2 in which is shown the manner in which a number of the modules 10 are inter-connected with a shot exploder 52 to provide a system for sequentially activating a series of detonators 54.1, 54.2, 54.3. The shot exploder 52 has outputs 56 and 58. These outputs are connected to the terminals 30 and 32 of the modules 10 by means of cables 60 and 62. Further, the terminal 40 of a first one of the modules 10.1 is connected to its terminal 32. By this means, the first module 10.1 is enabled so that when a calibration signal is supplied to the system via the cables 60 and 62 the NAND gate 38 of the module 10.1 is enabled. It will further be noted that the mode control output terminal 50 of each module is connected to the mode control input terminal 40 of the next module. It will thus be understood that when the shot exploder 52 generates its energising signal, all the modules 10 are energised. When the first

calibrating signal is supplied it is routed by the pulse discriminators 34 of all the modules to their associated NAND gates 38. However, as only the first module 10.1 will be supplied with a calibrating enable signal by its terminal 40, only the timing arrangement 12 of that module 10.1 will go into its calibration mode with its calibrating counter 22 recording the number of signals supplied by the oscillator 14 whilst the calibrating signal is present. Thus, at the beginning of the first calibrating signal 66 (as shown in Figure 3(a)) having a duration of  $T_1$  the signal supplied to the input 38.1 of the NAND gate 38 changes from a low to a high. The output of the NAND gate 38 accordingly goes low causing the flip-flop 44 of the first module 10.1 to change state as is shown at 68 in Figure 3(b). At the end of the first calibrating signal, the signal supplied to input 38.1 again changes from a low to a high such that the output of the NAND gate 38 goes low, causing the flip-flop 44 to once again change state. At this state the output of the flip-flop 44 goes low causing the flip-flop 46 to be set, and go high, as is shown at 70 in Figure 3(c). The fed-back signal disables the NAND gate 38. Further, the high signal from the flip-flop 46 of the first module 10.1 is inverted and supplied via its output terminal 50 to the input terminal 40 of the next module 10.2 which in turn enables the NAND gate 38 of that module. Thus, when the next calibrating signal 72 having a duration of  $T_2$  is supplied, it is routed to the timing arrangement 12 of the module 10.2. At the end of the second calibrating signal 72 the R-S flip-flop 46 of the second module 10.2 is set, causing its output to go high as is indicated at 74 in Figure 3 (d). As was indicated earlier, a high signal supplied by the flip-flop 46 of any module 10 places its timing arrangement 12 in an operative mode. Thus, after a time period equal to  $32 \times T_1$  after the R-S flip-flop 46 of the first module 10.1 has changed state, a firing signal is supplied to its associated detonator 34.1 via its output terminal 28. Similarly, a time interval  $32 \times T_2$  after the R-S flip-flop 46 of the second module 10.2 has changed state, its detonator 54.2 is supplied with an activating signal. It will be appreciated that the interval between activation of the detonator 54.1 and activation of the detonator 54.2 will be  $T_2 + 32(T_2 - T_1)$ . Thus, as the last module in a series thereof is calibrated some time after the first module, its oscillator has to be stable for a much shorter time than if it had been calibrated at the same time. Further, with the invention, each module may be separately calibrated with a different time interval, if so desired.

#### Claims

1. An activating module for a sequential activating system having a series of the modules, which includes
  - a timing signal generating means for generating a timing signal;
  - a mode control means for supplying a calibration mode signal, an operative mode signal,

and an output mode switching signal to be supplied to a successive module in a series thereof;

- 5 a calibrating recording means for recording the timing signal when in a calibration mode and for supplying a recorded calibration signal;
- 10 an operative timing signal determining means responsive to the mode control means for determining when the timing signal generating means has generated an operative timing signal, when in the operative mode, that has a predetermined relationship to the recorded calibration signal and for supplying a prompting signal which is supplied directly to a detonator or to a further processing means when the operative timing signal has been generated;
- 15 a calibrating signal supply connection means for connecting the module to a shot exploder which supplies a series of calibrating signals for successive modules in a series thereof;
- 20 a first gate means, responsive to the mode control means, the output of which is supplied to the calibrating recording means whilst the appropriate calibrating signal is extant;
- 25 a mode control input connection means for receiving an input mode switching signal that the module is to go into its calibration mode and for supplying the input mode switching signal to the mode control means;
- 30 a second gate means, responsive to the mode control means, connecting the timing signal generating means with the operative timing signal determining means; and
- 35 a mode control output connection means for supplying the mode switching signal to a successive module in a series thereof.

- 40 2. A module as claimed in Claim 1, in which the timing signal generating means includes an oscillator.
- 45 3. A module as claimed in Claim 1, in which the timing signal generating means includes an oscillator for generating a series of signals and the calibrating recording means includes a calibrating counter for counting and recording the number of signals generated by the oscillator whilst the calibrating signal is extant.

- 50 4. A module as claimed in Claim 3, in which the operative timing signal determining means includes a timing counter for counting the number of signals generated by the oscillator and a comparator for comparing the count of the timing counter with that of the calibrating counter, and supplying an output signal when the two counts are equal.

- 55 5. A module as claimed in Claim 4, in which the comparator has an output for resetting the timing counter and the operative timing signal determining means includes a further counter for counting the number of times the comparator supplies its output signal and for supplying the prompting signal when it has counted a predetermined number.

- 60 6. A module as claimed in Claim 1, in which the mode control means has a sensing means for
- 65

sensing the termination of the calibrating signal received by it after receipt by it of the input mode switching signal and for then supplying the operative mode signal.

- 70 7. A module as claimed in Claim 6, in which the mode control means supplies the operative mode signal and the output mode switching signal at the same time.

- 75 8. A module as claimed in Claim 1, in which the mode control means has a latch feedback connection for latching itself upon supplying the operative mode signal to maintain the supply of this signal.

- 80 9. A module as claimed in Claim 3, in which the mode control means supplies the calibration mode signal, after receipt by it of the input mode switching signal, for so long as it receives the calibrating signal, and the calibrating counter then counts the number of timing signals generated by the oscillator during the duration of the calibration mode signal.

- 85 10. A module as claimed in Claim 1, in which the mode control means comprises a network of logic elements.

- 90 11. A module as claimed in Claim 1, which includes a detonator connection means for connection to a detonator.

- 95 12. A sequential activating system which includes

- a shot exploder for supplying power and a series of calibrating signals;

- a series of modules as claimed in any one of the preceding claims, with the calibrating signal supply connection means of each module being connected to the shot exploder, the mode control input connection means of a first module in the series being connected to the shot exploder, and the mode control input connection means of a second and each successive module in the series being connected to the mode control output connection means of its immediately preceding module.

- 100 13. A method of activating a series of detonators which includes

- providing a series of activating modules;
- supplying a calibrating signal to a first one of the modules and successive calibrating signals to successive modules in the series; and
- with each module
  - a) generating internally a timing signal;
  - b) placing it in a calibration mode;
  - c) supplying it with the appropriate calibrating signal having a predetermined time duration;
  - d) determining and recording the value of timing signal equal to that calibrating signal
  - e) placing the module in an operative mode;
  - f) determining when the timing signal generated during the operative mode has a predetermined relationship to the recorded value of the timing signal, and
  - g) activating a detonator associated with that module when the timing signal generated during the operative mode attains the predetermined relationship.

- 105 14. An activating module for a sequential

activating system, substantially as described in the specification with reference to the accompanying drawings.

15. A sequential activating system,  
5 substantially as described in the specification with 10

reference to the accompanying drawings.

16. A method of activating a series of detonators, substantially as described in the specification with reference to the accompanying drawings.

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